Review Article

Saturation Diving and Its Role in Submarine Rescue

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Abstract

Saturation Diving is a highly technical and advanced form of diving utilized to perform dives at depths greater than 55 metres. It employs physiological principles and decompression techniques which enables the diver to have an almost unlimited stay at the depth. This requires the diver to be saturated at the requisite pressure in a diving chamber for prolonged periods. Saturation diving necessitates stringent fitness standards of divers, careful and exhaustive planning of the dive, creating tailor made breathing mixtures, a high level of medical preparedness and response, continuous scrupulous monitoring of the divers' physiological and environmental parameters and long term follow up to obviate any unwanted outcome. The purpose of Saturation diving is to provide cost effective and extensive period of stay underwater to perform useful work at great depths. It is employed commercially for exploration and maintenance of offshore platforms such as oil rigs and militarily for submarine rescue and salvage of sunken aircraft and ships. In Submarine rescue, it provides the valuable back up and training effort. The limitations of Saturation diving are: highly technical equipment which is expensive and maintenance intensive, prolonged training of personnel and meticulous execution of the dive is mandatory.

Key Words : Diving medicine, Submarine medicine

Introduction

Saturation diving as a concept grew out of both the need and the fascination to dive deeper. However, due to the peculiarity of the ideal gas laws, at depths deeper than 55 metres, the inert gas load in the human tissues become unmanageable and the decompression regimen required to harmlessly get rid of this inert gas load becomes impractical. For instance, a 10 minute exposure in Helium - Oxygen (Heliox) mixture at 100 metres of sea water mandates a decompression schedule of close to 3 hours. This precluded doing any useful work at such depths due to the extremely punishing decompression schedule. The solution to this seemingly insurmountable problem came from a series of experiments conducted by Captain George Bond of US Navy called as 'Genesis' from 1957 to 1962.[1,2] Captain Bond and his team managed to create a pressurized artificial breathing environment for experimental animals (Wistar Rats) in which they could survive almost indefinitely without any demonstrable ill effects. This paved the way for human trials and ultimately development of Saturation Diving.

Physiological Basis

The Haldanian concept of decompression assumes a logarithmic scale of dissolution of inert gas into human tissue based on the pressure and the type of tissue. It dictates that after six "half lives" of exposure, the tissue will be nearly fully saturated with the inert gas and further dissolution of inert gas in the tissue would be extremely slow and can be considered as "saturated". This also means that the

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decompression obligation required to harmlessly get rid of the inert gas will also be stabilized after such a time period of exposure. Hence, the decompression schedule will attain a maximal peak after the tissue has been fully saturated and will become constant irrespective of any further time of exposure to pressure. This physiological modeling of tissues based on the Haldanian model and modified by Workman,[3,4] forms the basis of Saturation diving. The diver is exposed to maximal duration of exposure at a particular pressure in order to make is tissues "saturated" hence, beyond this duration of the exposure, the decompression obligation is constant. Going back to the example of the 100 metre dive, after a 12 hour saturation exposure, the decompression regimen will stabilize at about 4 days duration. Therefore, after this saturation exposure, the diver can perform work at the depth for unlimited period of time and will have a constant decompression period.

Equipment and Procedures

Applying this physiological basis practically, involves a highly technical pressure chamber with life support facilities as well as accurate gas mixing and delivery systems. The divers are saturated in pressure chambers and live in these chambers till the end of their decompression obligations which can run into weeks. They are transferred to the requisite depth by a complicated mechanism of pressurized transfer modules into a "diving bell" which descends into the water. At the depth, the divers "lock out" from the diving bell carrying their breathing gas supplies through long pressurized hoses called "umbilical", to perform the work and then return to their living chamber at its conclusion. All these interconnected chambers require constant monitoring of the physiological and environmental parameters as well as visual monitoring. The pressure need to be scrupulously maintained in all these systems although it is possible for the diver to alter his depth in a narrow range centered on the pressure of the living chambers. This depth is called the "living depth" or the "storage depth". The variations in the pressure are called as "Excursions".

Medical Aspects

Even a minor medical problem manifesting inside the chamber can prove to be very dangerous as very little medical help can be provided inside the chamber till the entire decompression schedule is concluded. Further, any infectious illness can rapidly spread inside the tiny precincts of the pressure chamber to all the inhabitants. Due to the high humidity environment, fungal infections can develop easily and require rigorous treatment. Therefore, it is of paramount importance to screen the divers carefully before the dive. Due to the exotic breathing environment, illnesses due to inappropriate mixtures may lead to hypoxia, oxygen toxicity or carbon dioxide toxicity. The chamber environment can also get contaminated from various sources; hence, continuous monitoring of Oxygen, Carbon dioxide and various contaminants of the chamber atmosphere is required. Due to the prolonged stay in confined environs, lack of any recreation and communication with friends and family, psychological problems may occur. It has to identified and addressed actively.[1,5]

The primary medical problem in Saturation diving, however, is Decompression Sickness (DCS). It is very likely to occur in the saturation diving setting even if the decompression schedule has been adhered to rigorously. This is prevented by careful planning of the dive and decompression schedule and monitoring the divers diligently during the course of the dive. A case of DCS during saturation diving may prove very difficult to treat as it will involve further compression and very slow decompression lasting for a much longer period than originally planned.[6]

Peculiar problems arise because of the unique breathing mixtures having major content of Helium. Due to its high thermal conductivity, even a mild variation in the chamber temperature can lead to hypothermia or hyperthermia. Voice changes occur in helium rich environment and normal conversation is not possible. At deeper depths and faster compression rates, in the helium environment, High Pressure Neurological Syndrome (HPNS) can cause seizures which can seriously debilitate the divers. Careful manipulation of the chamber environment is done to treat HPNS.

There are long term morbidities associated with Saturation Diving. Dysbaric osteonecrosis and decreased lung function have been known to occur. Also, mild memory loss and personality changes have been reported after repeated and frequent Saturation Diving exposures. Hence, long term follow up of the divers is necessary to detect and treat these illnesses.

Submarine Rescue

In the military setting, saturation diving provides support during submarine rescue. Submarine rescue is carried out with a Submarine Rescue Bell (SRB) which is a pressurized chamber capable of mating with a disabled submarine to evacuate the submarine[1,7] escapees. The system incorporates the basic elements of traditional saturation diving platforms to provide life support to divers at the worksite as well as in a decompression chamber in between work assignments. The deployment and execution of the SRB for submarine rescue requires careful manipulations for effective mating which is done through the Saturation Diving capabilities. Saturation diving is done to provide human intervention at the hatch of the disabled submarine.[8] Further, the training and research in furthering the submarine rescue capabilities can only be done through the saturation diving facilities. The personnel who are involved in submarine rescue require the Saturation Diving facilities as back up.

Conclusion: The way ahead

With the requirement to send humans to deeper depths underwater, saturation diving techniques[9,10] continue to grow. The techniques involved in Saturation Diving, even after half a century of practice are far from perfect. Long term effects of such diving on the diver and the physiological changes remain to be understood comprehensively. Decompression techniques and strategies have to be refined further to achieve greater depths as well as minimize the chances of DCS. In this quest, newer gases and gas mixtures are being experimented and simultaneously,[11] their physiological effects need to be studied. The Decompression theory and practices require to be continuously researched for the various gas mixtures. Interestingly, this has beneficial spin offs in other fields such as medicine and space research. Improved and new saturation diving standards will lead to better practices in the fields of hyperbaric oxygen therapy, aerospace medicine and confined space living situations.

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References

1. Johnson JM. Saturation diving as a submarine rescue tool. Life Support Biosph Sci. 1996 Winter; 2(3-4):133-43.
2. RJ Vaernes, H Klove, B Ellertsen. Neuropsychologic effects of saturation diving. Underse Biomed Res. 1989. 16 (3): 233- 251.
3. G Jacobsen, JE Jacobsen, RE Peterson, JH Mclellan, ST Brooke, T Nome, AO Brubakk. Decompression sickness from Saturation Diving: a case control study of some diving exposure charachteristics. Undersea Hyperb Med 1997: 24 (2): 73 - 80.
4. J Wang, S Barth, M Richardson, K Corson, J Mader. An outbreak f Methicillin-resistant Staphylococcus aureus cutaneous infection in a saturation diving facility. Undersea Hyperb Med 2003: 30 (4): 277 - 284.
5. E Thorsen, K Segadal, BK Kambestad. Mechanisms of reduced Pulmonary function after a saturation dive. Eur. Respir. J. 1994: 7: 4-10.
6. K Todnem, Nyland, H Skeidsvoll, R Svihus, P Ricnk, BK Kambestad, T Riise, JA Aarli.

   Neurological long term consequences of deep diving. British Journal of Industrial Medicine. 1999; 48: 258 - 266.
7. Einar Thorsen, Kare Segadal, Brit KAmbestad, Amund Gulsvik. Divers' lung function: small airways disease? British Journal of Industrial Medicine 1990; 47: 519 - 523.
8. Alf O. Brubakk, John A.S. Ross, Stephen R. Thom. Saturation Diving; Physiology and Pathophysiology. Compr Physiol 2014, 4: 1229-1272. doi: 10.1002/cphy.c130048
9. Blatteau JE1, Hugon J, Castagna O, Meckler C, Vallée N, Jammes Y, Hugon M, Risberg J, Pény C. Submarine rescue decompression procedure from hyperbaric exposures up to 6 bar of absolute pressure in man: effects on bubble formation and pulmonary function. PLoS One. 2013 Jul 2;8(7):e67681. doi: 10.1371/journal.pone.0067681. Print 2013.
10. Brown DC. Submarine escape and rescue in today's Royal Navy. J R Nav Med Serv. 1999;85(3):145-9.
11. Parker EC1, Ball R, Tibbles PM, Weathersby P K. Escape from a disabled submarine: decompression sickness risk estimation. Aviat Space Environ Med. 2000 Feb; 71(2) : 109-14.